

CLAIMS

1. A method of functionalising a powdered substrate, which method comprises the following steps:
  - i) passing a gas into a means for forming excited and/or unstable gas species;
  - ii) treating said gas such that upon leaving said means the gas comprises excited and/or unstable gas species which are substantially free of electric charge; at a temperature below 500°C;
  - iii) treating the powdered substrate with said excited and/or unstable gas species and a functionalising precursor in a downstream region external to the means for forming excited and/or unstable gas, wherein neither the powdered substrate nor the functionalising precursor have been subjected to steps (i) and (ii) and wherein said functionalising precursor is introduced simultaneously with or subsequent to introduction of the powdered substrate;
  - iv) collecting resulting functionalised substrate.
2. A method in accordance with claim 1 wherein the means to generate excited and/or unstable gas species is an electrical discharge apparatus.
3. A method in accordance with claim 1 or 2 wherein the powdered substrate and/or functionalising precursor is/are treated by the excited and/or unstable gas species in a container.
4. A method in accordance with claim 3 wherein the container is a fluidised bed and/or circulating bed reactor.
5. A method in accordance with claim 4 wherein the gas comprising excited and/or unstable gas species is utilised as the gas in the fluidised or circulating bed for suspending powders, and/or droplets of liquid.

6. A method in accordance with any preceding claim wherein the liquid and/or gas functionalising agent is in the form of a liquid compound, a solution of a high viscosity liquid or solid compound in either a liquid carrier or a liquid co-reactive and/or a molten solid.
7. A method in accordance with claim 6 wherein the liquid functionalising precursor comes into contact with the powder substrate either in the presence of or not in the presence of the excited and/or unstable gas species.
8. A method in accordance with any preceding claim wherein the functionalising precursor is introduced in the form of an atomised liquid.
9. A method in accordance with claim 3, 4 or 5 wherein the atomised liquid is introduced into the container at any position by direct injection.
10. A method in accordance with any one of claims 1 to 5 wherein the liquid and/or gas functionalising agent is an organometallic compound of titanium, zirconium, iron, aluminium, indium and tin or mixtures containing one or more thereof.
11. A method in accordance with any one of claims 1 to 5 wherein the liquid and/or gas functionalising agent is an organometalloid compound of germanium or silicon.
12. A method in accordance with claim 11 wherein the organometalloid compound is selected from an organosilane and an inorganic silane where the inorganic groups are selected from halogeno, hydrogeno, or hydroxyl groups, and mixtures thereof.
13. A method in accordance with claim 12 wherein the organosilane is a functionalised silane containing one or more of the following organic groups

bearing functionalities such as:- alkenyl, aryl, H, OH, amino groups, aldehyde groups alkyl halide groups, alkyne groups amido groups, carbamate groups, urethane groups, organic salts, carboxylic acid groups and their derivatives such as acid anhydride groups, organic groups containing boron atoms, or phosphorus, or sulphur containing groups such as mercapto, or sulphido groups or grafted or covalently bonded biochemical groups such as amino acids and/or their derivatives, grafted or covalently bonded biochemical species such as proteins, enzymes and DNA.

14. A method in accordance with claim 11 wherein the organometalloid compound is an organopolysiloxane having a viscosity of from 0.65 to 1000 mPa.s.
15. A method in accordance with any one of claims 1 to 5 wherein the functionalising precursor is an organic compound.
16. A method in accordance with any one of claims 1 to 15 wherein the powdered substrate is selected from one or more of a compound selected from the group of a metallic oxide, a metalloid oxide, a mixed oxide, an organometallic oxide, an organometalloid oxide, an organo mixed oxide resin, and/or an organic resin.
17. A method in accordance with any one of claims 1 to 15 wherein the powdered substrate is selected from one or more of the following:-  
metals, metal oxides, silica and silicates, carbon, carbon nanotubes, carbon and silicon nanostructures, organic powdered substrates, including polymeric, dyestuffs, fragrances, flavourings, pharmaceutical powdered substrates such as penicillins and antibiotics as well as biologically active compounds for example proteins, including grafted or covalently bonded biochemical groups such as amino acids and/or their derivatives, grafted or covalently bonded biochemical species such as proteins, enzymes and DNA and other protein based materials, silicone resins, mineral fillers such as for example carbon

black, clays,  $\text{CaCO}_3$ , talc, silica, biogenic silica, mica conductive fillers,  $\text{TiO}_2$  nanoparticles, metal oxides such as  $\text{TiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{B}_2\text{O}_3$ ,  $\text{Li}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{PbO}$ ,  $\text{ZnO}$ , or,  $\text{CaO}$ ,  $\text{Pb}_3\text{O}_4$  and  $\text{CuO}$  and mixed oxides, graphite, phosphorus particles, organic and inorganic pigments and the like; metalloid oxides, mixed oxide, organometallic oxides, organometalloid oxides, organomixed oxide resins and/or an organic resin, sodium carbonate potassium nitrate, silicon metal particles, silicone rubber crumb, organic rubber crumb such as EPDM and polypropylene, wood dust and/or plastics.

18. A method in accordance with any preceding claim wherein the product of step (iii) is retreated with an excited and/or unstable gas species and/or a functionalising precursor.
19. A method in accordance with claim 18 wherein a catalyst selected from a mild basic organic compound and a mild basic inorganic compound is utilised to catalyse a multi-step process involving a condensation reaction.
20. A method in accordance with claim 18 a substrate is subjected to an Oxidative plasma post-discharge treatment to promote oxidation and condensation reaction.
21. A functionalised powdered substrate prepared in accordance with the method of any one of claims 1 to 20.
22. A functionalised powdered substrate in accordance with claim 21 wherein the substrate is selected from the powdered substrates of claim 17 which has been functionalised according to functionalities described in claims, 10,11,12 or 13.
23. An apparatus for making functionalised particles by the method of claims 1 to 15 or 17 comprising a means for generating an excited and/or unstable gas species, a means adapted to introduce the powder substrate, and a means to introduce a gaseous and/or liquid precursor into said excited and unstable gas

species in a downstream region external to the means forming excited and/or unstable gas, and a means for collecting resulting functionalised powder.

24. An apparatus in accordance with claim 23 wherein said apparatus forms a part of a fluidised or circulating bed.
25. An apparatus in accordance with claim 23 or 24 wherein the means adapted to introduce a gaseous and/or liquid precursor is an atomiser.
26. An apparatus in accordance with any one of claims 23, 24 or 25 wherein means for generating an excited and/or unstable gas species is an electrical discharge assembly.
27. Use of functionalised powder particles in accordance with any of claims 21 or 22 in optoelectronics, photonics, flexible electronics, optical devices, transparent electrically conductive films, displays and solar cells or as thermally conductive fillers, biotechnology, biosensors, detergents, filtration, household cleaning, rubber and plastic recycling, and or separation applications.
28. A functionalised powder obtainable by the method in accordance with any one of claims 1 to 20.